DOI: 10.1007/s11676-007-0003-2

Estimation of the carbon storage of forest vegetation and carbon emission from forest fires in Heilongjiang Province, China

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Abstract: The forest resource of Heilongjiang province has important position in china. On the basis of the six times of national forest inventory data (1973–1976, 1977–1981, 1985–1988, 1989–1993, 1994–1998, 1999–2003) surveyed by the Forestry Ministry of P. R. China from 1973 to 2003, the carbon storage of forests in Heilongjiang Province are estimated by using the method of linear relationship of each tree species between biomass and volume. The results show that the carbon storage of Heilongjiang forests in the six periods (1973–1976, 1977–1981, 1985–1988, 1989–1993, 1994–1998, 1999–2003) are 7.164×10^8 t, 4.871×10^8 t, 5.094×10^8 t, 5.292×10^8 t, 5.594×10^8 t and 5.410×10^8 t, respectively., which showed a trend of decreasing in early time and then increasing. It indicated that Heilongjiang forests play an important role as a sink of atmospheric carbon dioxide during past 30 years. Based on the data of forest fires from 1980 to 1999 and ground biomass estimation for some forest types in Heilongjiang Province, it is estimated that the amount of mean annual consumed biomass of forests is 391758.65t–522344.95t, accounting for 6.4%–8.4% of total national consummation from forest fires, and the amount of carbon emission is 176 291.39t–235 055.23t, about 8% of total national emission from forest fires. The emission of CO_2, CO, CH_4 and NMHC from forest fires in Heilongjiang Province are estimated at 581761.6–775682.25 t, 34892.275–46523.04 t, 14091.11–18788.15 t and 6500–9000 t, respectively, every year.

Keywords: Forest vegetation; Carbon storage; Forest fire; Biomass; Carbon emission

Introduction

Carbon storage of forest ecosystem is a basic parameter of studying carbon exchange between forest ecosystem and atmosphere, and an essential factor of estimating the absorption and discharge of forest ecosystem (Wang *et al*. 1995). Russia, Canada, USA and so on have had a great progress in research on estimation of carbon storage of the forest ecosystem (Alexeyev *et al*. 1995; Apps 1994; Turner *et al*. 1995; Wang *et al*. 1994). The Chinese scholars also began to study forest carbon storage in China and studied the carbon storage and dynamic change characteristic mainly in the national or the climatic zone scale (Wang *et al*. 1995; Fang *et al*. 2001; Liu *et al*. 2000; Wang *et al*. 2000; Zhou *et al*. 2000; Yan *et al*. 1995). However, their studies have not attached more attention to small region scale, just only some southern regions in China (Zhang *et al*. 2002; Ding *et al*. 2004; Cao *et al*. 2002; Wang *et al*. 2004).

Foundation project: This study was supported by National Natural Science Foundation of China (No.30471404), National Doctoral Subject Fund of China (No.20040225003), Natural Science Fund of Heilongjiang Province (ZJD04-0102), and Research Program of Science and Technology of Heilongjiang Province (GB05B602).

Received: 2006-04-02; Accepted: 2006-11-26

Electronic supplementary material is available in the online version of this article at http://dxdoi.org/10.1007/s11676-007-0003-2

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Responsible editor: Chai Ruihai

Heilongjiang Province is rich in not only forests but also forest fires. Frequent occurrences of forest fires, especially heavy forest fires damages the natural ecosystem, at the same time releases lots of carbon-containing greenhouse gases, which has great effect on the whole world environment. From 1970s, some foreign scholars have started to estimate the emission of greenhouse gases from forest fires (Wong 1979; Cruzten *et al*. 1979; Goldammer *et al*. 1993; Levine *et al*. 1995). Some Chinese scholars also began to study the emission of greenhouse gases because of forest fires in the late of 1990s (Wang *et al*. 1998; Tian *et al*. 2003). Presently, researches on carbon emission from forest fires concentrates mainly on not small scale but larger scale. Therefore, the study of carbon emission from forest fires in Heilongjiang Province is essential in order to quantify carbon contribution from forest fires to the atmospheric carbon balance, appraise important functions of forest ecosystem in high latitude region of China, offer scientific basis for reducing uncertainty of estimation of carbon balance in global change research.

This paper analyzes the carbon storage and dynamic changes of forests in Heilongjiang Province for around 30 years and offers their development situations based on six-time forest inventory data.

Study site and data collection

Heilongjiang Province is located between 43°25′–53°23′ North latitude and 121°11′–135°5′ East longitude and the climate of the province is continental climate, cold and dry in winter, hot and rainy in summer, dry and windy in spring. The forest coverage of Heilongjiang reaches 39.54%, the forested area $1\,797.50\times10^4$ hm^2, and the forest volume is $137\,502.31\times10^4$ m^3, the regional vegetation is cold temperate coniferous forests and temperate coniferous and broad-leaf mixed forests. Natural forest is larger than planted forests.

The research data are collected from six-time forest inventories of China, including forest area and volume. The data of forest fires come from forest fire statistics.

Study methods

Biomass estimation

At present, the Volume-biomass method (Liu *et al*. 1996; Fang *et al*. 1998) is considered as a better estimation method of forest biomass. The conversion relationship between volume (X_v) and biomass (Y_b) is as follows:

$$Y_b = aX_v + b \tag{1}$$

where, the X_v and Y_b express the forest volume (m^3) and biomass (t) respectively. And a and b are parameters which come from Fang *et al*. (1996).

There is a good linearity relationship between total average biomass and volume (Fang *et al*. 2001; Fang *et al*. 1998; Brown *et al*. 1992) and the relationship is invariable with different times. Therefore, this paper also adopts the total regression equation between biomass and volume (Fang *et al*. 2001):

$$Y=0.5751X+38.706 \quad (n=120,\ r^2=0.83) \tag{2}$$

Estimation of carbon storages

The estimating method for carbon storages of forest vegetation was applied widely based on relationship between biomass and volume (Dixon *et al*. 1994). The international conversion rate between plant biomass and carbon is 0.45 (Olson *et al*. 1983) and 0.50 (Levine *et al*. 1995). The conversion rate of 0.45 was adopted in this article.

Estimation of biomass losses

An equation proposed by Seiler *et al.* (1980) for estimating the consumed biomass from forest fires was adopted in this study:

$$M=A\times B\times a\times b \tag{3}$$

where, M is the consumed biomass (t), A the burned area (hm^2), B the average biomass ($t\cdot hm^{-2}$), a the proportion of aboveground biomass, and b the combustion efficiency of biomass.

Results and data analysis

Carbon storages and its dynamic changes of forest vegetation

The area and carbon storages of national forest and Heilongjiang forest were shown in Table 1. The carbon storages of national forests showed an increasing tendency from 1973 to 2003, with an annual increment of 0.317×10^8 t. Carbon storage of Heilongjiang forests increased during 1977–1998, with an annual increment of 3.286×10^6 t. The results of six times of forest inventory from 1973 to 2003 demonstrate that the carbon storage of Heilongjiang forest accounts for 31.982% (1973-1976), 20.852% (1977–1981), 21.533% (1984-1988), 20.175% (1989–1993), 19.184% (1994–1998) and 16.780% (1999–2003) of that of whole China forests, respectively, and the carbon density of forests in Heilongjiang Province are 0.824×10^1 $t\cdot hm^{-2}$, 0.841×10^1 $t\cdot hm^{-2}$, 1.070×10^1 $t\cdot hm^{-2}$, 0.978×10^1 $t\cdot hm^{-2}$, 1.017×10^1 $t\cdot hm^{-2}$ and 1.167×10^1 $t\cdot hm^{-2}$ higher than those of whole China, respectively.

Table 1. Forest area and total carbon during six periods from 1973 to 2003 in China and in Heilongjiang Province

Inventory time	China					Heilongjiang Province				
	Forest area (hm^2)	Total volume (m^3)	Total biomass (t)	Total carbon (t)	Carbon density ($t\cdot hm^{-2}$)	Forest area (hm^2)	Total volume (m^3)	Total biomass (t)	Total carbon (t)	Carbon density ($t\cdot hm^{-2}$)
1973–1976	1.102E+08	8.656E+09	4.978E+09	2.240E+09	2.033E+01	2.508E+07	2.125E+09	1.592E+09	7.164E+08	2.857E+01
1977–1981	1.007E+08	9.028E+09	5.192E+09	2.336E+09	2.321E+01	1.526E+07	1.437E+09	1.083E+09	4.871E+08	3.162E+01
1984–1988	1.072E+08	9.141E+09	5.257E+09	2.366E+09	2.206E+01	1.555E+07	1.317E+09	1.132E+09	5.094E+08	3.276E+01
1989–1993	1.137E+08	1.014E+10	5.830E+09	2.623E+09	2.307E+01	1.611E+07	1.348E+09	1.176E+09	5.292E+08	3.285E+01
1994–1998	1.344E+08	1.127E+10	6.479E+09	2.916E+09	2.170E+01	1.756E+07	1.411E+09	1.243E+09	5.594E+08	3.187E+01
1999–2003	1.749E+08	1.246E+10	7.163E+09	3.224E+09	1.843E+01	1.798E+07	1.375E+09	1.202E+09	5.410E+08	3.010E+01

Carbon storages and its dynamic changes of planted forest and natural forest

Table 2 shows the area and carbon storages of planted forest and natural forest in Heilongjiang Province from 1973 to 2003.

The carbon storages of planted forests increased yearly in the six-time forest inventories in Heilongjiang Province, and the carbon density of planted forests in Heilongjiang Province had also an increasing tendency in the six periods of forests inventory from 1973 to 2003, with two peak values of 1977–1981 and 1999–2003.

The characteristic of forests in Heilongjiang Province is that the proportion of natural forests is more significant. The carbon storages of natural forests in Heilongjiang Province decreased by 6.572×10^8 t per year from 1973 to 1981 and then increased by 5.142×10^6 t per year, and arrived at peak value at 1998. The carbon density of natural forests also showed an increasing tendency in the six periods of forests inventories from 1973 to 2003, and arrived at peak value at 1998.

Estimation of consumption biomass from forest fires

The mean biomass of various forests types every year can not be estimated exactly because the area and average biomass of forests in Heilongjiang Province always changed from 1980 to 1999. This article adopts the area and volume data of different forest types from 1994 to 1998 in Heilongjiang Province (Table 3). The total and average biomass of various forests types in Heilongjiang Province can be obtained by using the relationship between biomass and volume. Mean ground biomass are calculated by using Eq. (1), in addition to the known proportion of ground

biomass to total biomass (Fang *et al.* 1996).

Wong (1979) proposed the conception of combustion efficiency for the first time. The combustion efficiency is an essential factor to estimate carbon-containing gas emission from forest fires. This paper takes combustion efficiency of temperate and north forest 0.09–0.12 (Aulair *et al.* 1993) as combustion efficiency of forests in Heilongjiang Province. Table 4 shows the burned area of different forest types in Heilongjiang Province during 1980–1999 (Jin *et al*. 2002; Jin 2002).

Consumed biomass of forest combustion is the products of burned area, mean ground biomass and biomass combustion efficiency. Consumed biomass of forest combustion in Heilongjiang Province during 1980–1999 is reported in Table 5.

Table2. Area and total carbon of planted forests and natural forests during six periods from 1973 to 2003 in Heilongjiang Province

Inventory time	Planted forests					Natural forests				
	Forest area (hm^2)	Total volume (m^3)	Total biomass (t)	Total carbon (t)	Carbon density ($t \cdot hm^{-2}$)	Forest area (hm^2)	Total volume (m^3)	Total biomass (t)	Total carbon (t)	Carbon density ($t \cdot hm^{-2}$)
1973–1976	8.800E+05	2.386E+07	1.372E+07	6.175E+06	7.017E+00	2.420E+07	2.101E+09	1.578E+09	7.103E+08	2.935E+01
1977–1981	6.446E+05	2.392E+07	1.957E+07	8.808E+06	1.366E+01	1.462E+07	1.413E+09	1.063E+09	4.783E+08	3.272E+01
1984–1988	1.616E+06	5.131E+07	4.070E+07	1.832E+07	1.133E+01	1.394E+07	1.266E+09	1.091E+09	4.911E+08	3.524E+01
1989–1993	1.504E+06	4.920E+07	2.829E+07	1.273E+07	8.464E+00	1.460E+07	1.298E+09	1.148E+09	5.164E+08	3.536E+01
1994–1998	1.922E+06	7.495E+07	4.311E+07	1.940E+07	1.009E+01	1.563E+07	1.336E+09	1.200E+09	5.400E+08	3.454E+01
1999–2003	1.698E+06	9.450E+07	5.435E+07	2.446E+07	1.440E+01	1.622E+07	1.281E+09	1.148E+09	5.166E+08	2.874E+01

Table 3. Biomass of different forest types in Heilongjiang Province from 1994 to 1998

Forest type	Area ($10^4 hm^2$)	Total volume ($10^6 m^3$)	Relationship between volume and biomass*	Total biomass ($10^6 t$)	Mean biomass ($t \cdot hm^{-2}$)	Ratio of ground biomass to total biomass	Mean ground biomass ($t \cdot hm^{-2}$)
Korean pine forest	48.40	43.831 8	0.518 5 / 18.22 / 0.953 / 17	22.727	46.957	0.80	37.566
Mixed Broad-leaved forest	90.30	78.853 6	0.625 5 / 91.001 3 / 0.93 / 19	49.323	54.621	0.83	45.335
Coniferous Broad-leaved mixed forest	68.61	79.580 9	0.801 9 / 12.279 9 / 0.998 / 9	63.816	93.013	0.79	73.480
Spruce and fir forest	21.77	15.591 5	0.464 2 / 47.499 / 0.99 / 13	0.072	0.331	0.79	0.261
Larch forest	389.65	330.4465	0.967 / 5.759 8 / 0.99 / 8	319.542	82.007	0.82	67.246
Mongolian scotch pine forest	27.38	21.367 3	$Y_b = 1.11X_v$	23.718	86.625	0.75	64.969

Notes: *---- $Y_b = aX_v + b$ (Fang *et al*. 1996); Model parameter between volume and biomass: a/b/R/n.

Table 4. Burned area of different forest types in Heilongjiang Province during 1980–1999

Year	Burned area (hm^2)					
	Korean pine forest	Mixed broad-leaved forest	Coniferous broad-leaved mixed forest	Spruce and fir forest	Larch forest	Mongolian scotch pine forest
1980	366.7	22621.2	59.1	9.6	1632.0	145.4
1981	275.6	165234.0	413.9	0.0	19141.5	0.0
1982	0.0	6872.3	614.9	0.0	141.5	0.0
1983	75.3	44027.8	1957.4	367.8	417.3	4.1
1984	0.0	11274.3	0.0	0.0	721.7	0.0
1985	214 0.9	4169.2	2.1	0.0	2.4	0.0
1986	0.0	28051.2	15.6	0.0	6384.2	978.9
1987	0.0	6830.2	141802.0	0.0	564219.0	78582.7
1988	0.0	564.3	0.0	0.0	113.4	0.0
1989	2.5	2690.4	0.0	0.0	92.9	21.0
1990	0.0	967.1	0.0	0.0	1427.8	0.0
1991	0.0	2925.8	0.0	0.0	4043.1	0.0
1992	127.4	4857.8	90109.1	0.0	9.2	0.0
1993	86.8	168.6	0.0	0.0	0.0	0.0
1994	0.0	3202.1	13563.9	0.0	3342.9	0.0
1995	13.6	28686.9	0.0	0.0	18.9	39.9
1996	180.4	805 0.3	27059.6	0.0	28651.2	2088.4
1997	0.0	1179.2	16.6	0.0	228.6	0.0
1998	0.0	1178.0	138.0	1.6	531 1.5	0.0
1999	41.2	1455.1	97.9	0.0	193 5.3	306.1

The estimate results reveals that the consumed ground biomass of various forest types is about 391 758.65–522 344.95 t every year from 1980 to 1999. In 1987, the consumed biomass was the most, which is caused by heavy forest fires in Daxing'an Mountain. Consumption biomass of forests in Heilongjiang Province is caused mainly by the forest fires of larch forest, coniferous broadleaved mixed forest and mixed broadleaved forest, in which consumption biomass of larch forest is the most. The consumption biomass of spruce and fir forests is the least, only 0.45–0.59 t every year.

Table 5. Consumed biomass of different forest types in Heilongjiang Province during 1980–1999

Year	Consumed biomass (t)						
	Korean pine forest	Mixed broadleaved forest	Coniferous broadleaved mixed forest	Spruce and fir forest	Larch forest	Mongolian scotch pine forest	Total
1980	1239.79–1653.05	92297.89–123063.85	390.84–521.12	0.23–0.30	9877.09–13169.46	850.18–113 3.58	104656.02–139541.36
1981	931.79–1242.38	674179.51–898906.01	2737.20–3649.61	0.00–0.00	115847.00–154462.70	0.00–0.00	793695.53–105826 0.71
1982	0.00–0.00	2800.01–37386.69	4066.46–5421.94	0.00–0.00	856.38–1141.84	0.00–0.00	32962.85–43950.47
1983	254.58–339.45	179 640.03–239 520.04	12944.68–1729.57	8.64–11.52	2525.56–336 .41	23.97–31.96	195397.46–260529.95
1984	0.00–0.00	460 00.84–613 34.45	0.00–0.00	0.00–0.00	4367.83–5823.78	0.00–0.00	50368.66–67158.22
1985	7238.25–9651.01	17010.96–22681.28	13.89–18.52	0.00–0.00	14.53–19.37	0.00–0.00	24277.63–32370.17
1986	0.00–0.00	114453.10–152604.14	103.17–137.55	0.00–0.00	38638.07–51517.43	5723.83–7631.78	158918.18–211890.90
1987	0.00–0.00	279205.48–372273.97	937765.00–1250353.00	0.00–0.00	3414732.00–4552977.00	459489.50–612652.70	5091192.39–6788256.53
1988	0.00–0.00	2302.43–3069.90	0.00–0.00	0.00–0.00	686.31–915.08	0.00–0.00	2988.74–3984.99
1989	8.45–11.27	10977.24–14636.31	0.00–0.00	0.00–0.00	562.24–749.66	122.79–163.72	11670.72–15560.96
1990	0.00–0.00	3945.91–5261.22	0.00–0.00	0.00–0.00	8641.25–115 21.66	0.00–0.00	12587.16–16782.88
1991	0.00–0.00	11937.70–15916.94	0.00–0.00	0.00–0.00	24469.41–32625.88	0.00–0.00	36407.11–48542.81
1992	430.73–574.31	19820.55–26427.40	595 909.50–794 546.00	0.00–0.00	55.68–74.24	0.00–0.00	616216.46–821621.95
1993	293.47–391.29	687.91–917.22	0.00–0.00	0.00–0.00	0.00–0.00	0.00–0.00	981.38–1308.51
1994	0.00–0.00	13065.05–17420.06	89700.78–119601.00	0.00–0.00	20231.70–26975.60	0.00–0.00	122997.53–163996.70
1995	45.98–61.31	117046.86–156062.47	0.00–0.00	0.00–0.00	114.39–152.51	233.30–311.07	117440.53–156587.36
1996	609.92–813.23	32846.43–43795.24	178950.50–238600.70	0.00–0.00	173401.10–231201.40	12211.31–16281.75	398019.29–530692.38
1997	0.00–0.00	4811.31–6415.08	109.78–146.37	0.00–0.00	1383.52–1844.69	0.00–0.00	6304.61–8406.15
1998	0.00–0.00	4806.42–6408.56	912.62–1216.83	0.04–0.05	32145.94–42861.26	0.00–0.00	37865.02–50486.69
1999	139.29–185.73	5937.03–7916.04	647.43–863.24	0.00–0.00	11712.71–15616.94	1789.83–2386.44	20226.29–26968.39
Average	559.61–746.15	82950.65–110600.85	91212.60–121616.80	0.45–0.59	193013.15–257350.85	24022.24–32029.65	7835173.57–10446898.09

Estimation of carbon-contained gases

It is an assumption that the carbon from burned biomass is changed into carbon-contained gases entirety. Total carbon (Mc) from forest fires is calculated according to having 45% (Tian *et al*. 2003) of carbon in forest biomass:

$$Mc = 0.45\times M \tag{4}$$

Generally, the emission of carbon dioxide is 90% (Crutzen *et al*. 1990) of the total carbon emission in forest fires. Thus, direct emission of carbon dioxide (M_{CO_2}) in forest fires is:

$$M_{CO2}=0.9\times0.45\times M\times (44/12) \tag{5}$$

The emission of carbon-containing gas can be calculated based on the ratio of the emission of one kind of carbon-containing gas to emission of carbon dioxide in forest fires (Emission Ratio). The ratio of carbon monoxide, methane and NMHC to carbon dioxide is 5.2/86.7 2.1/86.7 and 1.0/86.7 respectively according to the standard gas emission ratio (Laursen *et al*. 1992; Yokelson *et al*. 1997). Table 6 summarizes the emission of carbon-containing gas in forest fires from 1980 to 1999.

The total emission of carbon from forests fires are 3 525 827.85–4701104.55 t in Heilongjiang Province from 1980 to 1999. The emission of carbon dioxide, carbon monoxide, methane and NMHC of forests are 5 8 1 7 6 1 .6–775 682.25 t, 34 892.275–46 523.04 t, 14 091.11–18 788.15 t and 6 500– 9 000 t respectively every year in Heilongjiang Province from 1980 to 1999, in which the emission of carbon dioxide is the most in 1987. The emission of carbon dioxide was caused mainly by the combustion of Larch forests not only because Larch forests has 4×10^6 hm^2 of forest areas but also its burned area reaches 31891 hm^2 every year.

Conclusions and discussion

The function of carbon sinks of forests in Heilongjiang

Results from this study suggest that carbon storages of forests in Heilongjiang Province play a dominant role in China, especially the natural forests. The carbon storages of forests are increasing year after year except that in the late of 1970s in Heilongjiang Province. After 1980, the carbon storages of forest vegetation in the Heilongjiang Province increased and reached 5.594×10^8 t during 1994–1998, which makes its function of natural carbon sinks reappearance. This is the result of right forest policy including strengthening the management and protection of wildwood and natural forests and increasing plantation intensity.

The carbon storages of the planted forest vegetation in Heilongjiang Province was 1.940×10^7 t in 1998, which demonstrate that the function of planted forest vegetation becomes stronger and stronger, and the planted forest vegetation will own latent giant carbon storages and build up carbon sink function.

The carbon density of forest vegetation in Heilongjiang Province is increasing, too. Thus the forests in Heilongjiang Province

have big potential as the carbon sinks if the forests in existence are fostered and managed better. The carbon storages and carbon density of forest vegetation increase unceasingly in Heilongjiang Province, which makes the vegetation system has a stronger carbon sink function.

Table 6. CO_2, CO, CH_4 and NMHC emissions from forest fires in Heilongjiang Province during 1980–1999 (t)

Year	CO_2	CO	CH_4	NMHC
1980	155414.16–207218.98	9321.26–12428.36	3764.36–5019.15	1792.56–2390.07
1981	1178637.82–1571517.59	70691.08–94254.80	28548.32–38064.44	13594.44–18125.92
1982	48949.83–65266.45	2935.86–3914.48	1185.64–1580.85	564.59–752.79
1983	290165.29–386886.90	17403.22–23204.29	7028.23–9370.96	3346.77–4462.36
1984	74797.46–99729.96	4486.12–5981.50	1811.70–2415.60	862.72–1150.29
1985	36052.28–48069.70	2162.31–2883.073	873.24–1164.32	415.83–554.44
1986	235993.53–314657.99	14154.17–18872.22	5716.11–7621.47	2721.96–3629.27
1987	7560420.12–10080561.65	453450.80–604601.16	183124.34–244165.85	87202.08–116269.45
1988	4438.28–5917.71	266.20–354.93	107.50–143.34	51.19–68.26
1989	17331.02–23108.03	1039.46–1385.95	419.78–559.71	199.90–266.53
1990	18691.93–24922.58	1121.09–1494.78	452.75–603.66	215.59–287.46
1991	54064.56–72086.07	3242.63–4323.50	1309.52–1746.03	623.58–831.44
1992	915081.50–1220108.67	54883.78–73178.38	22164.60–29552.81	10554.57–14072.76
1993	1457.35–1943.13	87.41–116.54	35.30–47.07	16.81–22.41
1994	182651.29–243535.10	10954.86–14606.49	4424.08–5898.77	2106.71–2808.94
1995	174399.14–232532.29	10459.93–13946.57	4224.20–5632.27	2011.52–2682.03
1996	591058.66–788078.21	35449.89–47266.51	14316.30–19088.40	6817.29–9089.71
1997	9362.35–12483.13	561.53–748.70	226.77–302.36	107.99–143.98
1998	56229.56–74972.74	3372.48–4496.64	1361.96–1815.95	648.55–864.74
1999	30036.04–40048.06	1801.47–2401.96	727.52–970.02	346.44–461.92
Total	11635232.16–15513644.91	693360.50–930460.82	280512.71–375763.03	134201.06–178934.77

The vegetation effect on carbon dioxide is one of important contents of global change research. The study of carbon storages and density is helpful to appraisal carbon source and sink function. Horizontal zonal distribution of China shows that carbon density and carbon storages of forest vegetation reduce with the increase of latitude at northeast but carbon density of vegetation of cold temperate and temperate coniferous forest is high (Wang *et al*. 1999). Many of cold temperate coniferous forests and temperate coniferous broad-leaved mixed forests in Heilongjiang Province are natural forests and nutrients and the population density is high. Thus the ability of carbon fixation and carbon density is high at this area. *Larix gmelinii* forest is a carbon sinks and absorbs carbon 2.65 $t\cdot hm^{-2}$ every year (Jiang *et al*. 2001). Therefore, the carbon storages and density of forests in Heilongjiang Province will have a promising development based on the protecting project of nature forests, de-farming and reforestation project and the three north shelterbelt programs and so forth.

Consumption of biomass of forests from forest fires

The consumption of ground biomass of various forests types is 783 517 3–104 468 99 t and 391 758.65–522 344.95t every year in Heilongjiang Province, which is 6.4%–8.4% of national consumption from 1980 to 1999 (Tian *et al*. 2003). Consumption of biomass is caused mainly by forest fires of larch forest, which is 48%–50% of other forest types.

Emissions of carbon and carbon-contained gases

Direct carbon emission of various forests types is 3 525 827.85–4 701 104.55t and 76 291.39–235 055.23t every year in Heilongjiang Province, which is 8% of that in China from 1980 to 1999 (Tian *et al*. 2003). The emissions of carbon dioxide, carbon monoxide, methane and NMHC in forest fires are 581 761.6–775 682.25 t, 34 892.275–46 523.04 t, 14 091.11–18788.15 t and 6500–9000 t respectively every year.

Differences of carbon dioxide emission of different forest types

The direct emission of carbon dioxide was caused mainly by the forest fires of larch forests, coniferous broadleaved mixed forests and mixed broadleaved forests, in which carbon dioxide emission of larch forests is the most as much as 286 624.53–382 166.01t every year. Carbon dioxide emission of coniferous broadleaved mixed forests and mixed broadleaved forests is 135 450.711–180 600.948t and 123 181.71525–164 242.26225t respectively every year. But carbon dioxide emission of spruce and fir forests is the least, only 0.67–0.87 t every year.

Influence factors on the emission of carbon-contained gases

The influencing factors on the emission of carbon-containing gas include forest types, serious degree of forest fires and the accurate emission ratio of carbon-containing greenhouse gases and so on. For instance, the emission of carbon-containing gases of larch forests is the most, coniferous broadleaved mixed forest takes second place and spruce and fir forest is the least. Area and serious degree of forest fires are influenced mainly by weather conditions.

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